6. BUILDING AND FIRE RESEARCH LABORATORY IN THE 90s

6.1 Overview

Fiscal year 1991 began auspiciously with fire research expert (and building research supporter) John Lyons the new NIST director, the Administration efforts to eliminate building and fire research ended, and a new Building and Fire Research Laboratory (BFRL) organized at NIST by merger of the Centers for Fire Research and Building Technology.

Jack Snell, deputy director of BFRL and former director of CFR, described the new organization as "half of a laboratory" in comparison with the size and funding of the other new NIST laboratories. BFRL management was resolved to correct this situation by working with leaders of the fire and building communities to produce and implement such excellent results, and define such national needs and plans to respond to them, that BFRL would attract the resources required to provide the needed performance prediction methods, measurement technologies, and technical advances. BFRL management also was resolved to correct its own "bunker mentality" and that of the staff created by seven years of Administration proposals for elimination or halving of the programs, and to attract the excellent new staff needed for technical leadership in the 90s and in the 21st century.

This chapter describes significant accomplishments and substantial disappointments. New directly appropriated funding was received: in 1992 for fire research and for earthquake engineering, in 1993 for green buildings, and in 1994 for high performance materials research. The White House gave priority to construction and building research in 1994 and CBT provided leadership for the multiagency coordinated program. These and the efforts and ingenuity of staff led to many significant, high-impact research results. However, the Congressional elections of 1994 created a divided government that was unable to focus its attention on needs for and benefits of building and fire research. In 1991 there were 195 total staff, this rose 20 percent to reach 216 in 1995, but declined again to 186 in 2000. To increase effectiveness with such constrained resources, BFRL focused most of its resources on six major products beginning in fiscal year 1998, but continued to give

attention to selected other topics likely to become the major products of the 21st century.

A series of annual and biannual reports provide a good summary of activities and references for this period [1-6].

6.2 1991

The Building and Fire Research Laboratory (BFRL) began operationally on October 1, 1990, and was established formally on January 31, 1991. Its mission was "increasing the usefulness, safety and economy of constructed facilities and reducing the human and economic costs of unwanted fires." It performed and supported "field, laboratory and analytical research on the performance of construction materials, components, systems and practices, and the fundamental processes underlying the ignition, propagation and suppression of fires." It produced " technologies to predict, measure and test the performance of construction and fire prevention and control products and practices." The organization was:

Headquarters: Richard Wright, director; Jack Snell, deputy director; James Gross, assistant director; and Kathryn Stewart, executive officer.

Structures Division: H.S. Lew, chief

Building Materials Division: Geoffrey Frohnsdorff, chief

Building Environment Division: James Hill, chief

Fire Science and Engineering Division: Andrew Fowell, chief

Fire Measurement and Research Division: Richard Gann, chief

Andrew Fowell had been deputy director of CFR and was reassigned as division chief to replace James Quintiere who had moved to the University of Maryland in 1990. The persons named above comprised the Management Council of BFRL.

The BFRL program was comprised of three major thrusts, each involving multiple divisions, with subelements as noted below:

Fire Research

1. Fire risk and hazard prediction
2. Fire safety of products and materials
3. Advanced technologies for fire and fire risk sensing and control

Earthquake Hazard Reduction

Construction Industry Competitiveness

1. Construction materials
   a. Service life prediction
   b. Advanced organic materials
   c. High performance concrete
   d. Quality assurance of construction materials testing laboratories
2. Structural Evaluation
   a. Condition assessment
   b. Structural response control
   c. Failure investigations
3. Building performance
   a. Alternative refrigerants
   b. Building controls
   c. Building envelope
   d. Computer-integrated construction
   e. Indoor air quality
   f. Lighting
   g. Test procedures for major energy appliances

The Building Program, comprised of Earthquake Hazard Reduction and Construction Industry Competitiveness, and the Fire Program essentially were continuations of the work of CBT and CFR.

The Principles and Values of BFRL, as discussed with the staff on August 3, 1990, were:

1. **Building and Fire Research programs continue.**
2. **Excellent public service.**
3. **Technical excellence in R&D and Technology Transfer**
4. **Advance fire and building science.**
5. **Responsive to mandates and public policies**
6. **Responsive and close to user communities**
7. **Build a new organization and develop esprit de corps**
8. **Open, candid, interactive, enthusiastic and productive people; teamwork and delight in our work.**
9. **Good environment for career development of staff**
10. **Simple, responsive, efficient organizational structure.**

There were cultural differences. Fire staff commonly lunched together combining divisions and groups; building staff did not. Weekly Fire seminars shared current research with the whole Fire staff; building staff would not voluntarily participate in seminars beyond group interests. An open house was held to give staff opportunities to see all the work of the laboratory and meet each other. Management and staff worked hard to make the laboratory seen as a merger, not an acquisition. Jack Snell took on double duties to make the laboratory succeed: he served as deputy director for the whole laboratory and continued as manager of the Fire Program. The Management Council assigned its members responsibility for developing "big chunks" of funding (multi-year programs of $1 million or more total funding, directly appropriated or funded by other agencies or the private sector) in contrast to the roughly $100 thousand per year projects that were best negotiated by group leaders or senior researchers and tended to diffuse BFRL's focus.

BFRL reached out to its community to gain ideas for, understanding of, and collaborators in its work.

- A three day workshop, involving 27 state fire marshals or chief deputies, was conducted with the National Association of State Fire Marshals to identify 15 project areas where BFRL research was needed to address critical issues affecting the Nation's fire service.
- A workshop of the International Council for Research and Innovation in Building and Construction (CIB) was hosted on fire model verification, selection and acceptance for fire safety engineering practice.
- The newly created Civil Engineering Research Foundation organized and held, with BFRL support and participation, the Civil Engineering Research Needs Forum, January 28-30, 1991. It attracted community leaders, including the chief engineers of the Army, Navy, and Air Force on the eve of the Kuwait war, and produced recommendations for national programs in high performance concrete and steel, national and international acceptance of innovative products and services, and integrated, computer-aided engineering design and construction.
- The report on Construction Technologies in Japan by the Japanese Technology Evaluation Center showed that the much greater Japanese investments in R&D for construction had given them leadership in high performance construction materials and in construction robotics.

Barbara Levin, Vytenis Babrauskas, and colleagues completed a comprehensive methodology, with minimal dependence on animal testing, for obtaining and using smoke toxicity data for fire hazard analysis. It built on two decades of research and national and international collaborations with the National Institute of Building Sciences, the Southwest Research Institute and others, and became the basis for standards of NFPA, ASTM and ISO.

William Danner and Mark Palmer developed the application protocol technique for the STEP (Standard for Exchange of Product Model Data) international standard effort. The application protocol provides a complete and unambiguous characterization of the data to be exchanged. The richness of construction data required this technique and it is used internationally for data for all types of products.

Takashi Kashiwagi received the Applied Research Award of NIST for his pioneering studies of the thermal degradation of PMMA, and the Silver Medal of the Department of Commerce for the rational characterization of the phenomenon of flame spread on materials.

6.3 1992

Congress appropriated an increase of $409,000 for earthquake engineering in 1992, the NIST director transferred an additional $200,000 for fire research, and earlier funding of $250,000 for alternative refrigerants and $250,000 for furniture flammability were made part of the BFRL base funding. Moreover, the President requested funding increases for 1993 of $1 million for earthquake engineering and $300,000 for computer integrated construction, but proposed cutting BFRL by $350,000 for administrative savings from the reorganization.

BFRL's strategic plan of November 1, 1991, maintained the program thrusts described for 1991, but augmented the BFRL mission:

- Increase the usefulness, safety and economy of constructed facilities.
- Improve the productivity and international competitiveness of the construction industry.
- Reduce the human and economic costs of unwanted fires.

Fire research divisions and groups were reorganized to distinguish their roles:

- Fire Safety Engineering Division, Andrew Fowell, chief, had groups:
  - Fire Protection Applications, Richard Bukowski, leader
  - Fire Modeling, Walter Jones, leader
  - Large Fire Research, David Evans, leader
- Fire Science Division, Richard Gann, leader, had groups:
  - Smoke Dynamics Research, George Mulholland, leader
  - Materials Fire Research, Takashi Kashiwagi, leader
  - Fire Sensing and Extinguishment, William Grosshandler, leader

Unfortunately, the very promising collaborations with the National Association of State Fire Marshals came to a halt. Subsequently, a journalist [7] attributed this to the Association's close links to the tobacco industry that opposed BFRL's research on cigarette ignition propensity.

Richard Gann led the development of a multi-million dollar, multi-year program with Air Force funding to develop replacements for the halogenated fire suppressants that will provide safety in aircraft and buildings while avoiding damage to the environment. The program built upon the experiences of BFRL and the Center for Chemical Sciences and Technology in developing energy efficient replacements for refrigerants that threatened the ozone layer.

In a series of laboratory and mesoscale experiments, David Evans and his colleagues demonstrated for the Minerals Management Service and the Environmental Protection Agency that burning is a rapid and cost effective method of removing oil spills from the surface of water. Howard Baum and his colleagues developed a large eddy simulation computer model to understand the dynamics of smoke plume motion and smoke particle deposition.

Geoffrey Frohnsdorff led the private sector planning group for the Civil Engineering Research Foundation and provided the secretariat for the multi-agency Infrastructure-Construction Task Group of the President's Office of Science and Technology Policy that prepared the 10 year, $2 billion to $4 billion, High Performance Construction Materials and Systems program for private and public sector initiatives.

James Gross, working with U.S. standards organizations, and representing the American National Standards Institute in the management of construction standards for the International Organization for Standardization (ISO), arranged for U.S. leadership of ISO standards committees for Building Performance, Concrete, Timber, Masonry, Structural Design Loads, and Building Environmental Design. Leadership opportunities were available because European interests were focused on European standards. U.S. involvement was important to assure that good, up to date, ISO standards existed when European standards were completed, without U.S involvement, and proposed for adoption by ISO.

BFRL was hurt and saddened by the untimely death of Albert Lin. In his two years with BFRL, he initiated an important and successful program for performance criteria and test methods for seismically base-isolated structures, and achieved professional recognition as coordinator of CIB Working

Commission 73, Natural Disasters Reduction, and as editor of the newsletter of the Earthquake Engineering Research Institute.

John Klote won the 1992 Best Paper Award from ASHRAE for Design of Elevator Smoke Control Systems for Fire Evacuation with his coauthor George Tamura of the National Research Council of Canada, and also received the honor of ASHRAE Fellow. Vytenis Babrauskas received the NIST Rosa Award for developing and standardizing new techniques for measuring the fire properties of materials. Edward Garboczi received the L'Hermite Medal from the International Union of Research and Testing Laboratories for Materials and Structures (RILEM) for his contributions to the understanding of concrete and other random structures through the simulation of porous microstructures and of transport phenomena. Kermit Smyth received the Silver Medal of the Department of Commerce for pioneering measurements of the chemical structure of flames. James Hill was elected Vice President of ASHRAE.

6.4 1993

Section 104(g) of the American Technology Preeminence Act of 1992 (PL 102-245, February 14, 1992 stated:

> *The fire research and building technology programs of the Institute may be combined for administrative purposes, only, and separate accounts for fire research and building technology shall be maintained. No later than December 31, 1992, the Secretary, acting through the director of the Institute, shall report to Congress on the results of the combination, on efforts to preserve the integrity of the fire research and building technology programs, on procedures for receiving advice on fire and earthquake research priorities from constituencies concerned with public safety, and on the relation between the combined program at the Institute and the United States Fire Administration.*

The report to Congress dated December 9, 1992 responded to each of the points cited in the Law. The Report summary stated:

> *The combination of the building technology and the fire research programs has brought both of these programs closer to the Director of NIST, thereby increasing their internal visibility. The increased scale of the Laboratory relative to either of the original centers has created the opportunity for BFRL to conduct outreach activities that neither of the Centers could afford previously. The combination has opened the possibility for a number of important synergistic programs of benefit to both of the communities served, and effected a modest administrative savings that has been used to increase technical activities. It is the desire and intent of all concerned within NIST to continue the development of the Building and Fire Research Laboratory.*

The advent of the Clinton Administration in January 1993 brought promise of doubling NIST's budget and an unprecedented political change in NIST's leadership. John Lyons was made Acting Undersecretary of Commerce for Technology, with the understanding that he would not be reappointed as NIST director. This was the first time that an NBS or NIST director had been replaced by an incoming administration, but was expected to become a precedent for the future. When the new Undersecretary, Mary Good, was confirmed, Lyons became a senior scientist at NIST until he was appointed director of the new Army Research Laboratory in late 1993. BFRL appreciated and would miss his understanding, leadership and support. To make a place for a political appointee at the National Oceanic and Atmospheric Administration, Ray Kammer was reassigned to NIST as deputy director and acting director. Samuel Kramer was reassigned as assistant director. Arati Prabhakar from the Defense Advanced Research Projects Agency became NIST director on May 28, 1993; she was NIST's youngest and first female director. Prabhakar, who had worked in microelectronics, was open minded and decisive on BFRL issues. As she became familiar with BFRL's program, she expressed a clear preference for programs supporting economic growth over those responding to legislative mandates such as fire safety and earthquake hazard reduction.

The President's requests for increases in appropriations for BFRL for 1993 were not funded by Congress, but Congress did provide an increase of $800,000 for green building technology (half of which was earmarked for

Iowa State University) and NIST reprogrammed $400,000 to the earthquake program and $200,000 to alternative refrigerants.

William Allen continued to advise BFRL with renewed enthusiasm for the potential of the new laboratory. Among his major points were:

1. BFRL must be close to and valued by customers, not just intermediary standards organizations or the Washington representatives (lobbyists) of companies, but leading architects, engineers, contractors, regulators and the executives of manufacturers.
2. To merit the attention of customers, BFRL must produce valuable products that respond to their problems or give them new opportunities. Our job is not done until our products are in beneficial use. We must participate in the implementation or our efforts may be wasted. Also, is not measurements and standards too limiting for the scope of BFRL products?
3. To define these products, assure their production and achieve their acceptance, BFRL must have senior staff that understand the customers needs and capabilities - people like William Allen - to assure us we are doing the right job as well as doing the job right. Generally, these will not be researchers, but they should be understanding of research and work well with researchers. (They can be researchers, David Didion, for instance, was close to leaders of equipment manufacturers to understand and respond to their needs.) Senior architects are particularly vital to BFRL's mission and customers.
4. BFRL's strategic vision must express its vital and credible role in a manner inspiring to both customers and staff. The understanding and enthusiasm of customers, and BFRL managers and researchers can get us great assignments and great results.

BFRL tested these ideas with leaders of the industry by convening an ad hoc working group on May 5-6, 1993. The participants were: Kenneth Reinschmidt, Vice President, Stone and Webster Engineering Constructors; Dean Stephan, President, Pankow Construction; Jerome Sincoff, President, HOK Architects; Steven Mitchell, Chairman, Lester B. Knight Engineering; Michael Martin, Manager, Consumer and Construction, GE Plastics; Steven Bomba, Vice President, Johnson Controls; James Nottke, Director, Technology Acquisition, Dupont; J. Roger Glunt, Glunt Building Company and President, National Association of Home Builders; Miles Haber, Monument Construction; Gerald Jones, Director of Codes Administration, Kansas City, MO; and Thomas Castino, President, Underwriters Laboratories. Their advice was:

1. Change the name to Building Systems Laboratory
2. Focus on the life cycle construction process and integration of its steps.
3. Emphasize existing buildings.
4. Become the national focal point for a database of critical information (for the life cycle construction process).
5. Relate directly to customers, intermediaries are inadequate.
6. Continue valued work on measurement and test methods and data.
7. Get a champion in Congress.

BFRL has acted on these recommendations with three exceptions. The name change was seen as undesirably inhospitable to the fire community, data is increasingly decentralized with Internet and BFRL has not seen a way to take overall responsibility and gain credit for accessibility and quality, and BFRL has yet to find a champion in Congress.

A major concern to BFRL and to the Panel for Building and Fire Research was the degradation of a number of BFRL's important research laboratories. Major problems existed in: the environmental controls and instrumentation for the large fire test facility; the operability of the large environmental chambers for research on heating, ventilating and air-conditioning systems; and the controls and hydraulics of the 53 MN universal structural testing machine. NIST laboratories in general were aging and in need of renovation, but BFRL facilities were not included in NIST renovation plans for the 20th century.

Richard Marshall studied the very limited wind measurements and very extensive wind damages in Hurricane Andrew of August 24, 1992, and produced recommendations for improving the wind load provisions of the Manufactured Home Construction and Safety Standard (MHCSS) to reduce wind damages to manufactured (mobile) homes. These resulted in MHCSS adopting ASCE Standard 7-88, Minimum Design Loads for Buildings and Other Structures, and in improvements to the ASCE standard.

Geraldine Cheok, William Stone, and H.S. Lew, in cooperation with Pankow Construction, completed experimental studies of hybrid, pre-cast, reinforced concrete beam to column connections for regions of high seismicity. Design recommendations were formulated and presented to the American Concrete Institute and to the Structural Engineers Association of California. By the end of the decade these became the basis for construction of the tallest reinforced concrete buildings ever built in California.

Lawrence Kaetzel and James Clifton developed HWYCON, an expert system on the durability of concrete for highways, to implement the results of NIST research and the Federal Highway Administration's Strategic Highway Research Program. Over 2,000 copies were distributed to and used by state and local highway departments.

George Walton completed CONTAM93, a multizone airflow and contaminant dispersal model with a graphical user interface to assist designers and researchers understand the effects of materials choices and heating, ventilating and air-conditioning systems design and performance on indoor air quality and radon transport.

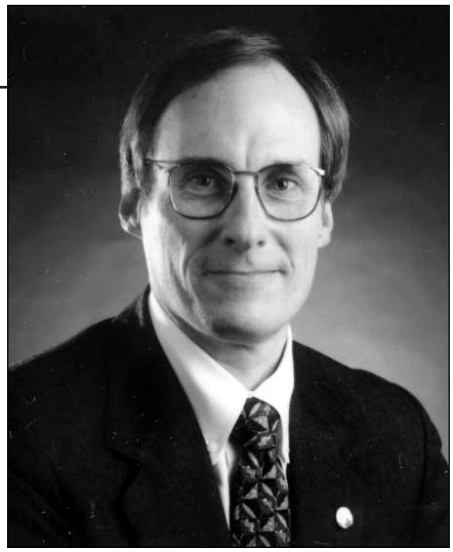
Nora Jason and colleagues implemented on Internet FIREDOC, the automated database of BFRL's Fire Research Information Services (FRIS), to greatly enhance access for fire protection engineers and researchers worldwide.

Mark Nyden and James Brown described how computer-aided molecular design can be used to achieve a new generation of fire resistant polymers. Cross linking can improve functional mechanical properties and promote formulation of heat resistant chars which reduce heat release rates during unwanted combustion.

6.5 1994

This was a euphoric year for NIST and BFRL. The perspective was given in Director Prabhakar's letter of January 19, 1994, to the National Research Council's Panel on Building and Fire Research:

> *As you know, President Clinton has proposed to increase the budget for the NIST laboratories from $193 million in 1993 to more than $430 million in 1997. This is a significant challenge for NIST. It gives us a chance to take control of our own future as we move away from dependence on other agency funding. Our general strategy is to offset some other agency funding with STRS funds and to increase staff by roughly 10 percent. We are also considering strategies for greater extramural collaboration with selected organizations.*



David Evans, chief, Fire Safety Engineering Division.

NIST also was receiving large increases in funding for the Advanced Technology Program (ATP) which cost-shared high risk industry research, and the Manufacturing Extension Partnership (MEP) which cost-shared technology transfer centers nationwide serving small and medium sized industry. ATP also supported BFRL research in collaboration with ATP grantees. BFRL worked with construction industry groups (most contractors are small or medium sized manufacturing industry), particularly the National Association of Home Builders, to explore establishment of one or more technology transfer centers for contractors. However, after

supporting studies of the potential for construction-oriented centers, MEP decided to focus its resources on discrete parts manufacturers.

The BFRL director's report to the Panel on April 19, 1994, stated:

> *The Building and Fire Research Laboratory has been identified by NIST management and the Administration as a major player in NIST's support of U.S. industry. Our base funding is proposed to increase from $12.1 million in FY 1993 to $21.7 million in FY 1995; our total program was $25 million in FY 1993. Major increases came in computer integrated construction, high performance construction materials and systems, alternatives to halon fire suppressants and CFC refrigerants, green building technologies and earthquake engineering. Senate- and House-passed reauthorization legislation for NIST calls for establishment of a National Wind Engineering Research program with NIST as lead agency; this should lead to new funding for wind engineering research including aspects of wind-driven fires. (Editor's Note - the Director's report was based on figures inconsistent with the final figures).*

There were increases of directly appropriated funds for 1994 of $200,000 for earthquake engineering, $100,000 for alternative refrigerants, $450,000 for high performance construction materials, $950,000 for computer integrated construction, and $4.5 million one-time funding for investigations related to the Northridge earthquake of January 17, 1994, Northridge, California earthquake.

However, the BFRL Management Council advised BFRL managers and staff to maintain good working relations with present and potential sponsors of work consistent with the BFRL Strategic Plan for two good reasons. First, collaborations with other agencies were among the best mechanisms for implementation of research, and, second, expectations for greatly increased directly appropriated funding might not be realized.

NIST defined its mission very simply to incorporate the work of the laboratories, the Advanced Technology Program, the Manufacturing Extension Program and the Baldrige National Quality Award:

> *To promote U.S. economic growth by working with industry to develop and apply technology, measurements and standards.*

In its 1994 Strategic Plan, BFRL expressed itself as:

> The national laboratory dedicated to the life cycle quality of constructed facilities.

BFRL's mission was expressed to support that of NIST:

> *To enhance the competitiveness of U.S. industry and public safety through performance prediction and measurement technologies and technical advances that improve the life cycle quality of constructed facilities.*

The BFRL program was expressed by three themes incorporating eleven program thrusts:

1. Advanced Technology for Constructed Facilities
   - High performance construction materials and systems.
   - Construction automation and robotics.
   - Reducing the hazards of natural disasters.
   - Affordable housing.
2. Advanced Fire Safety Technologies
   - Performance fire standards
   - Fire-safe products and materials
   - Advanced technologies for fire sensing and suppression
   - Large/industrial fires.
3. Green Building Technologies
   - Green buildings
   - Alternate refrigerants
   - Halon alternatives.

President Clinton established the National Science and Technology Council (NSTC) in 1993 to focus and coordinate R&D investments across the federal agencies. With strong support from John Gibbons, the President's Science Advisor, and Mary Good, Undersecretary of Commerce for Technology, the Civil Engineering Research Foundation and other industry groups, NSTC established a Subcommittee on Construction and Building (C&B) in April 1994. Richard Wright and Arthur Rosenfeld, scientific advisor the Assistant Secretary of Energy for Conservation and Renewable Energy, were chosen as co-chairmen of C&B. Andrew Fowell

accepted the position of Associate Director of Construction and Building in BFRL to serve as secretariat of C&B.

In meetings of the fourteen participating agencies of C&B, and in meetings with industry, the vision, mission, and National Construction Goals of C&B were established. The vision was:

- High quality constructed facilities support the competitiveness of U.S. industry and everyone's quality of life.
- U.S. industry leads in quality and economy in the global market for construction products and services.
- The construction industry and constructed facilities are energy efficient, environmentally benign, safe and healthful, properly responsive to human needs, and sustainable in use of resources.
- Natural and manmade hazards do not create disasters.

The mission of C&B was to enhance the competitiveness of U.S. industry, public and worker safety and environmental quality through research and development, in cooperation with U.S. industry, labor and academia to improve the life-cycle performance and economy of constructed facilities.

The National Construction Goals were:

1. 50 percent reduction in project delivery time
2. 50 percent reduction in operation, maintenance and energy costs
3. 30 percent increase in productivity and comfort
4. 50 percent fewer occupant related illnesses and injuries
5. 50 percent less waste and pollution
6. 50 percent more durability and flexibility
7. 50 percent reduction in construction work illnesses and injuries.

The baseline for each goal was industry performance in 1994, and the objective was to make available by 2003 practices capable of meeting the goals. Many initially felt the goals were incredible, but only the 7th came to seem to need revision. It was insufficiently challenging. Even in 1994, the best construction projects and firms, such as the members of the Construction Industry Institute, had injury rates of 1/7 the industry average.

David Evans became chief of the Fire Safety Engineering Division. In addition to his vigorous leadership of BFRL's studies for burning oil spills and for advances in simulation and modeling of fire phenomena, Evans became president of the Society of Fire Protection Engineers.

The enthusiastic response of the industry and agencies to the C&B program led to the President giving top-six priority to C&B funding for his fiscal year 1996 Budget Request to Congress. Never before, to the knowledge of the members of C&B, had an administration given top priority to research for construction.

A landmark report was completed on methodologies to evaluate fire suppressants for in-flight fire in aircraft. The evaluation includes suppressant effectiveness under harsh conditions, compatibility with materials and people, and environmental cleanliness. The methods were used to identify an optimum substitute for halon 1301 for certifying the fire suppression system effectiveness for engine nacelles.

A series of large-scale crude oil burns were completed near Prudhoe Bay, Alaska, in cooperation with Alaska Clean Seas. Smoke particulate measurements, both close to the fire and several kilometers downwind, were made to assess the impact of the burns and evaluate BFRL's Large Eddy Simulation (LES) model of the fire plume flow. Alaska adopted the model as part of its approval process for intentional burning of oil spills. Calculations using worst case atmospheric conditions indicate that ambient air quality standards are not exceeded beyond 5 km from a burn. This distance has been adopted in burning guidelines throughout the U.S.

A new computer model, called LEAK, was developed to predict the shift in composition of zeotropic refrigerant mixtures during slow or fast leaks to assure that new refrigerant mixtures do not leak flammable vapors.

BFRL led the reconnaissance team of the Interagency Committee on Seismic Safety in Construction investigating the January 17, 1994 Northridge California earthquake, and issued the report Performance of Structures, Lifelines and Fire Protection Systems in the 1994 Northridge Earthquake. A number of projects were initiated with

$4.5 million supplemental funding to gain knowledge for improvement of construction and fire safety practices. These projects were performed in cooperation with industry and universities and included research in repair and strengthening of welded steel moment connections, performance of lifeline systems, mitigation of large-scale fires and the performance of fire suppression on large-scale fires in neighborhoods.

James Hill received the Gold Medal of the Department of Commerce for outstanding management of the Building Environment Division. Richard Gann received the Silver Medal of the Department of Commerce for leading fundamental and important studies of the ignition propensity of cigarettes under careful and hostile scrutiny by the tobacco industry.

6.6 1995

BFRL and NIST peaked early in 1995. Budget increases for fiscal year 1995 included: green building technology $0.45 million, halon replacements $0.45 million, and high performance construction materials and systems $ 2 million. NIST funded a new competence project on high heat flux measurements led by William Grosshandler of BFRL and conducted jointly with the Physics Laboratory and the Chemical Science and Technology Laboratory.

James Hill, in a dual role as program manager for the Advanced Technology Program and as chief of BFRL's Building Environment Division, helped organize a focused, five year, $50 million program on Advanced Vapor Compression Refrigeration Systems for the refrigeration industry. Its goals were to increase system efficiency, reduce noise levels and reduce component sizes, each by 25 percent, and to prevent refrigerant leaks.

The Congressional elections of November 1994, led to Republican majorities in the House and Senate that were not simply in opposition to the Democratic administration, but sought major changes in government. Bills were introduced to eliminate the Department of Commerce (H.R. 1756, The Department of Commerce Dismantling Act) and the Advanced Technology Program was particularly attacked as welfare for industry. In this atmosphere, the $6 million construction and building initiative proposed by the President for BFRL was dropped by Congress without any direct attention.

The Office of Applied Economics returned to BFRL after a fourteen year organizational stay in the Computing and Applied Mathematics Laboratory (CAML). Harold Marshall led the Office from its founding as the Building Economics Section in CBT in 1973, through its stay in CAML, and again in BFRL. Although the Office had worked with the other NIST laboratories, the Advanced Technology Program and the Manufacturing Extension Partnership, it maintained close professional and program relations with BFRL and readily was reincorporated in BFRL. An example accomplishment in fiscal year 1995, was the release by Stephen Weber and Barbara Lippiatt of ALARM 1.0, Decision Support Software for Cost-Effective Compliance with Fire Safety Codes. The optimization method was field tested in nearly 100 hospitals with cost savings averaging between 30 percent and 35 percent of the cost of traditional code compliance strategies.

BFRL revised its program strategy to support the program of the Subcommittee on Construction and Building (C&B) of the National Science and Technology Council and its National Construction Goals. Although Congress had not supported the President's request of new funding for fiscal year 1996, C&B retained high priority in the Administration. The BFRL program had three thrusts and eight major products:

High Performance Construction Materials and Systems

- Performance standard for dwellings
- Integrated knowledge system for high performance concrete

Automation of Facilities and Processes

- Building automation control
- Automated condition assessment
- PlantSTEP

Loss Reduction

- Fire simulator
- Wind engineering standards
- Lifeline seismic standards

Could BFRL take advantage of the Administration's priority for the C&B program and the strong industry interest it created? BFRL had the strong

researchers, experts in transfer of results to practice, and record of significant accomplishments needed for credibility, but management felt it needed to be focused on appropriate contributions to accomplishment of the National Construction Goals if these were to be the basis for growth of BFRL. This was an extraordinary opportunity to become more than "half of a laboratory."

BFRL management knew an extraordinary effort would be required to align the staff, in spirit and in practice. Survival of individuals and groups through the reductions of the 80s had depended largely on their abilities to provide sound, measurement-oriented work palatable to NBS/NIST management, to attract funding from other agencies through personal contacts, and collaborate with industry and standards organizations for implementation of results. How many program themes had been used over the years to exploit transient initiatives of administrations and concerns of industry (housing, rehabilitation, energy conservation, solar energy, workplace and consumer safety, disaster mitigation, productivity, competitiveness, etc.) and yielded little in terms of lasting new resources and program growth in quality and quantity? Staff had reason to be cynical.

Doug Brookman was engaged as facilitator for what was named originally an "Alignment" initiative. He met with members of the Management Council, and representative group leaders, researchers and support staff to explore feelings about an alignment initiative:

1. Why is this a problem and why should BFRL address it now?
2. What are the barriers/impediments to a more complete organizational alignment?
3. How can we make this initiative successful?
4. Where are the best opportunities?

He found significant doubt and cynicism about the prospects for the initiative. It would require real commitment by Richard Wright and Jack Snell and engagement of a majority of BFRL's employees.

The name of the initiative was changed to "BFRL Success" to make the purpose clear. The Management Council and staff were informed:

1. We need to develop a strategy to assure the success and survival of BFRL. The present political environment is perilous, but provides opportunities we need to seize to assure our future.
2. We identified six keys to success:
   - Administration (White House, Commerce, NIST) support
   - Congressional support
   - Industry support
   - OA funding
   - Significant accomplishments
   - Active participation and commitment of the entire laboratory.

Diversity in the workforce had become an important objective for the Administration and NIST. Charles Yancey, an African American and

Charles Yancey, structural research engineer and chairman of NIST's Diversity Board.

Structural Research Engineer in BFRL since 1970, in 1994 became chairman of NIST's Diversity Board which advised NIST's management on its diversity programs. BFRL created its Diversity Plan in March 1995 with thrusts for:

1. Development of candidates for employment
2. Recruitment of staff
3. Development and retention of staff.

James Hill led an ad hoc committee to review the plan and recommend actions BFRL should take to further its Diversity goals. As a result, BFRL formed a Diversity Committee, subsequently chaired by Kathy Butler and then by Nelson Bryner, which became the prototype for diversity committees of NIST laboratories and led to NIST awards for their leadership.

On December 1, 1994, the President signed Executive Order 12941, Seismic Safety of Existing Federally Owned or Leased Buildings. The Executive Order implemented the Standards of Seismic Safety for

Existing Federally Owned or Leased Buildings. The Executive Order and the Standards were drafted by the Interagency Committee on Seismic Safety in Construction (ICSSC) which represented 30 federal agencies. BFRL provided the chairman (Richard Wright), chairman of the Subcommittee on Building Standards (H.S. Lew) and secretariat (Diana Todd) for ICSSC. ICSSC had prepared the proposed executive order prior to the Northridge Earthquake of January 17, 1994, to be ready for consideration when earthquake hazards again received high level attention.

The January 17, 1995, earthquake which struck Kobe, Japan killed more than 6,000 people, injured more than 30,000 and caused economic losses of $200 billion. H.S. Lew and Riley Chung of BFRL led a team, with members from other federal agencies, academia and industry, to study seismology, geology, and geotechnical effects, as well as the performance of buildings, lifelines and fire safety systems. Key findings of the investigation included needs for research and improvements in practices to achieve earthquake hazard reduction in the U.S. The study was conducted under the auspices of the U.S./Japan Panel on Wind and Seismic Effects, for which BFRL provided the U.S.-side chairman (Richard Wright) and secretariat (Noel Raufaste).

Geoffrey Frohnsdorff received the William T. Cavanaugh Memorial Award of ASTM for technical leadership in the initiation and development of international standards for construction materials and systems. Mary McKnight received the ASTM Award of Merit and honorary title of Fellow for administrative and technical leadership of Committee E06 in the development of standards for the abatement of hazards from lead paint in buildings.

Piotr Domanski developed CYCLE_D, a model for simulating vapor compression refrigeration cycles in preliminary refrigerant screening, system design, education and training. It could simulate systems using up to 38 different refrigerants and refrigeration mixtures with up to five components. It was published as Data Base 49 of the NIST Office of Standard Reference Data and distributed initially to over 60 customers. Also, the NIST Slichter Award was won by David Didion, Piotr Domanski and Mark Kedzierski for their work in finding alternatives to the refrigerants banned from production to protect the atmosphere.

BACnet, a data communication protocol for building automation and control network, was approved as ASHRAE Standard 135-1995. Steven Bushby was a major contributor to the standardization and then organized a consortium of 17 partners to assist members in developing products conforming to the standard and to develop conformance testing tools and procedures for an industry-run certification program.

William Pitts led a team providing the first understanding of the mechanisms leading to high concentrations of CO and extensive smoke-induced deaths from flashed-over enclosure fires. The results were incorporated into an algorithm which defined the amounts of CO generated for a given fire scenario, and showed that small scale toxicity tests are not adequate for characterizing the toxicity of smoke from real fires.

Richard Gann led the team that provided the technical basis for the selection of HFC-125 as the substitute for halon 1301 for suppressing in-flight air craft fires. Research included the dynamics of fire suppressant release, two-phase pipe flow, and the character of the spray. The results were adopted by the Boeing Company for the 777 airplane and by the U.S. Navy. William Grosshandler received the Silver Medal of the Department of Commerce for his technical leadership of this work.

David Evans received the Silver Medal of the Department of Commerce for leadership of analytical, laboratory and field studies of burning oil spills as a means to minimize environmental damage.

6.7 1996

The flow of new directly appropriated funding ended with fiscal year 1995. None was received for 1996 and, in spite of continued Administration pri-

ority for construction, no initiatives received support for 1997. However, Mary McKnight of BFRL led a team including researchers from the Physics, Manufacturing Engineering and Information Technology Laboratories which was awarded a five-year NIST competence project on color appearance. The objective was to develop models and measurement methods for predicting the appearance of coated objects.

Degradation of BFRL facilities remained a major issue. Failure of the smoke cleaning system for the large fire test facility caused its shut down. The efficiency of fire research was much inhibited by the extra expense and staff time required to conduct tests in others' facilities - some as far away as Japan. Funding from the Department of Energy was obtained to renew a portion of the environmental laboratories. BFRL cosponsored with the National Science Foundation a study of national needs for large scale structural experimental facilities for earthquake engineering and other purposes. One issue was whether BFRL's large scale structural testing facility should be renovated to become a national user facility. Still, NIST's plan for renewal of facilities provided nothing for BFRL in the 20th century.

The budget stalemate between Congress and the Administration caused a three week shutdown of NIST and other agencies beginning in mid-December 1995. A severe snowstorm kept NIST shut down for several more days after funding was restored. NIST cancelled its assessment panel meetings for 1996 to give staff more opportunity to catch up on research. Many BFRL staff had continued to work at home during the shutdown; by year's end there was no detectable loss of accomplishments from the shutdown.

The Administration continued to give priority to construction and building research. Meetings were held with industry sectors (housing convened with the National Association of Homebuilders, commercial and institutional convened with the National Institute of Building Sciences, public works convened with the American Public Works Association, and industrial convened with the Construction Industry Institute) to identify each sector's priorities among the National Construction Goals and to explore opportunities for joint programs.

NIST's Manufacturing Extension Partnership (MEP) funded, with technical support from Shyam Sunder of BFRL, a study by the National Association of Home Builders Research Center of the potential for one or more technology transfer centers for home builders [8]. Industry interest was high but MEP, in the end, did not find justification for extending its mission from small and medium size manufacturers, in general, to home builders and to their suppliers, which are dominantly large manufacturers.

The National Conference of States on Building Codes and Standards brought together about forty private sector organizations, with support from the NSTC Subcommittee on Construction and Building, to explore streamlining the building regulatory system. Streamlining would involve coordination and cooperation among the many local, state and federal regulatory authorities responsible for approving aspects of each construction project. It was anticipated that the time and cost involved in getting regulatory approvals could be halved without any relaxation of safety or environmental protections.

The BFRL program continued to focus on major products. The more general Computer Integrated Knowledge System replaced the Integrated Knowledge System for High Performance Concrete, and William Stone's Real Time Construction Site Metrology was added.

In light of NIST's focus of its resources on economic growth and international competitiveness, BFRL negotiated with FEMA to transfer to FEMA the responsibility for support of development of seismic safety standards for lifelines. It seemed impossible to obtain the necessary funding through the NIST budget and FEMA could build upon its successful program for development of seismic standards and practices for buildings. FEMA and NIST cosponsored the Lifeline Policy Makers Workshop in January 1997. FEMA then supported

the organization by the American Society of Civil Engineers of the American Lifelines Alliance to facilitate the development of guidelines and national consensus documents for improving the performance of utility and transportation lifelines subjected to natural hazards.

The results of BFRL research cited at the NIST Director's program review included:

1. Dale Bentz's and Edward Garboczi's work on modeling the chloride diffusivity of concrete to allow service life prediction for structures exposed to chlorides.

2. Steven Bushby's advancement of standard communication protocols for building automation and control systems from the 1995 ASHRAE standard to status as an ANSI standard and a European pre-standard and to consideration as an ISO standard. A consortium of 18 companies began developing protocols for conformance testing, and research began on extension to electrical load management, fire detection and suppression, and access and security systems. Bushby received the Slichter Award of NIST for this work.

3. Walter Jones' and colleagues development of CFAST and FASTlite as practical methods for modeling the fire performance of building designs. These methods provided the technical basis for performance based design of fire safety systems and were used world wide in fire safety engineering practice and education.

4. Kent Reed's and Mark Palmer's leadership of the production of the Application Protocol 227, Plant Spatial Configuration for automatic exchange of information in process plant design. The PlantSTEP consortium was formed with owners, engineering construction firms and CAD systems vendors to advance automatic exchange of information in process plant design, construction, operations and maintenance.

James Hill became President of the American Society of Heating, Ventilating and Air-Conditioning Engineers (ASHRAE) for 1996-1997 in recognition of his personal leadership in ASHRAE programs. He and many other BFRL staff have participated for years in cooperative ASHRAE-NIST efforts to improve knowledge, standards and practices and the national and international competitiveness of U.S. products and services.

The White House presented a "Hammer Award" for the BACnet demonstration project at the Phillip Burton Federal Office Building in San Francisco. BFRL worked with the General Services Administration, the Department of Energy, the Federal Energy Management Program, and the Lawrence Berkeley Laboratory in this demonstration of the performance improvements and cost savings to be realized from implementation of the BACnet communication protocol for building automation.

Noel Raufaste led the work to produce BFRL's Video, Your Partner in Building that received a 2nd place Telly Award for production excellence and the prestigious Crystal Award of Excellence from a Communications Awards competition. This award is presented to entrants whose ability to communicate elevates them above the best in the field.

William Pitts received the Silver Medal of the Department of Commerce for his research that identified the important mechanisms for production of life-threatening carbon monoxide in fires.

6.8 1997

This first year of the second Clinton Administration saw major changes in the leadership of NIST, the Department of Commerce and the White House Office of Science and Technology Policy. William Daley became Secretary of Commerce and called Ray Kammer from his position as Deputy Director of NIST to become Acting Assistant Secretary for Administration. Robert Hebner, a career NIST researcher and manager, was called upon to become Acting Deputy Director of NIST from his permanent position as Deputy Director of the Electronics and Electrical Engineering Laboratory. Arati Prabhakar resigned as Director of

NIST for a position in industry, and Hebner served as Acting Director until Ray Kammer was nominated and confirmed as NIST Director. Neil Lane moved from Director of the National Science Foundation to become the President's Science Advisor and Director of the Office of Science and Technology Policy (OSTP) replacing John Gibbons. Mary Good resigned as Undersecretary for Technology of the Department of Commerce; her deputy Gary Bachula then served as Acting Undersecretary.

The Construction and Building Subcommittee of the National Science and Technology Council continued to receive Administration priority. The Partnership for Advancement of Technology in Housing (PATH) was developed with active support in the White House contributing to the enlistment of leaders of the housing industry and its suppliers. PATH was designed to bring together government and industry to develop, demonstrate and deploy housing technologies, designs, and practices that could significantly improve the quality of housing without raising the cost of construction. The Department of Housing and Urban Development (HUD) and the Department of Energy became co-leaders for PATH. NIST was recognized as a key technical participant and supported by OSTP for a fiscal year 1999 budget increase for PATH. However, NIST gave higher priority to a Climate Change initiative, which was not funded by Congress, while HUD succeeded in gaining new funding for PATH. BFRL did receive substantial funding from HUD for technical support of PATH.

James Gross retired as Assistant Director of BFRL. Since 1971 he had been a leader for NBS/NIST in developing funding for and conducting housing technology and in building standards and codes programs. He was recognized for these accomplishments by the Department of Commerce Silver Medal, the Conference of States Award of the National Conference of States on Building Codes and Standards, the Award of Merit and of Honorary Fellow from ASTM, and the President's Award of the American Society of Civil Engineers. As Deputy Director of CBT in the 1980s he was a great source of strength in mobilizing support of industry for the survival of building and fire research at NBS, and in managing for continuing productivity while dealing with decreasing funding and reductions in staff. He was many times helpful to a division chief when tight funding required development and implementation of a "solvency plan" including lending staff to other organizations or assisting in their work, reducing expenditures to those essential, developing new sources of funding and reductions in force.

Joel Zingeser joined BFRL as manager of standards and codes services. Building on his background with the housing industry and applying his strong teambuilding skills, he played a major role in the development of PATH. Indeed, he coined the name and acronym in an early meeting of the agencies involved, represented NIST in the White House team that worked with industry to develop the program, and worked with HUD and BFRL managers to develop the technical support BFRL would provide to HUD for PATH.

BFRL joined the Construction Industry Institute (CII) in fiscal year 1995 because its goals were consistent with the National Construction Goals and because collaborations with CII offered unparalleled opportunities to work directly with leading executives from major owners of constructed facilities (such as Dupont and General Motors) and major engineering construction firms (such as Bechtel and Fluor-Daniel). CII declined to participate in any program to realize the National Construction Goals because it did not want to be directed by the federal government or report on its work to the federal government, but it welcomed the collaboration of BFRL and other federal agencies in its own programs. Richard Wright and Jack Snell became members of CII's Board of Advisors, Wright served on the Strategic Planning Committee and Snell on the Breakthrough Research Committee, Robert Chapman on the Benchmarking and Metrics Committee, and William Stone on project committees concerned with automation and metrology in construction.

CII since 1983 had focused on development of best practices for design

and construction and had demonstrated the value of their application for safety, and for schedule and cost control in its Benchmarking and Metrics Summary for 1997. However, CII felt best practice efforts might be approaching diminishing returns and decided to explore larger scale, breakthrough programs capable of producing major improvements in quality, safety and economy. The May 1997 Strategic Plan of CII identified Fully Integrated and Automated Project Processes (FIAPP) as a trend that will revolutionize construction. FIAPP meant the fully automated, one-time data entry, seamless integration of the project life-cycle work processes (from project inception through ongoing operation), including automated knowledge-based decision making, use of institutionalized intelligence and common databases. The Breakthrough Research Committee began work on development of a FIAPP program for CII with BFRL as an active participant.

NIST's Visiting Committee on Advanced Technology advised NIST in those times of difficult budgeting to provide closure in its mission statements - to show the consequences of not properly funding a mission. Consequently, BFRL added the word assure to its mission:

To enhance the competitiveness of U.S. industry and public safety through performance prediction methods, measurement technologies, and technical advances needed to assure improvement of the life cycle quality and economy of constructed facilities.

Disaster mitigation again became an element of BFRL's Success Strategy and BFRL participated in activities of the National Disaster Reduction Subcommittee of the National Science and Technology Council:

- National Mitigation Strategy
- US/Japan Earthquake Mitigation Partnership
- US/Japan Earthquake Policy Symposium
- Lifeline Policy Makers' Workshop
- Wind Peril Workshop

The focus on major products was strengthened to almost 2/3 of BFRL's directly appropriated funding. The major products became:

- Partnership for high performance concrete technology
- Performance standard system for dwellings
- Fire-Safe Polymers/Composites
- Fire Safety Performance Evaluation System
- Computer-Integrated Construction Environment
- Cybernetic Building Systems

In addition to major products, with their 3 year to 5 year time frame for results and 5 year to 10 year time frame for impacts, it was essential to prepare for the principal issues and major products of future years.

Greg Linteris, fire research engineer and NIST's first astronaut, is performing materials and combustion science research in the orbiting STS-94 Microgravity Space Science Laboratory.

Richard Gann headed a task force that included BFRL's NIST fellows (Emil Simiu, David Didion, and Howard Baum) and some of its liveliest younger researchers (Edward Garboczi, Anthony Hamins and William Pitts) to identify topics likely to become the ruling technologies in ten or so years. BFRL planned to invest 10 percent to 15 percent of its directly appropriated funding and focus its recruitment in preparing for leadership in the most important of these topics.

Gregory Linteris was NIST's first astronaut with two space flights (STS-83 in April and STS-94 in July) in the Microgravity Science Laboratory Mission. The first flight was curtailed after a few days because of mechanical problems, but because of the importance of the mission it flew again in July. Linteris conducted highly successful studies of soot formation, spherical flame structures, and combustion of atomized fuels.

Barbara Lippiatt developed and beta-tested a powerful technique for assessing the environmental and economic performance of building products called BEES (Building for Environmental and Economic Sustainability) to help manufacturers demonstrate the sustainability of their products and to help owners, designers, and builders make economical and sustainable choices.

Douglas Burch released an enhanced version of MOIST, a computer program that predicts the transfer of heat and moisture in walls, flat roof and cathedral ceilings. MOIST determined whether ventilation strategies achieved acceptable moisture performance to prevent build up of moisture and resultant degradation in walls or roofs, or the growth of mold on interior surfaces.

Edward Garboczi and Dale Bentz produced a pioneering "electronic monograph" available on Internet to predict concrete properties as a function on mixture design, curing and environmental exposure.

William Stone and Geraldine Cheok received the Structural Engineering Award of the American Concrete Institute for their paper Performance of Hybrid Moment Resisting Precast Beam-Column Concrete Connections Subject to Cyclic Loading which provided the basis for building code acceptance of seismically resistant multi-story precast concrete framed buildings.

6.9 1998

NIST director Ray Kammer and the Laboratory Council, which was comprised of the directors of NIST laboratories, gave substantial attention to "best in the world" programs of NIST. Presentations were made to NIST staff on the "best in the world" programs, and the question was asked implicitly, why should we have programs where we are not best in the world or striving to become that? BFRL's major products aimed squarely at best in the world. But programs, such as BFRL's role in the National Earthquake Hazards Reduction Program, where it was useful but not even best in the program, became candidates for restructuring or reprogramming. The Laboratory Council defined the goal of NIST's laboratories' research as "research planned and implemented in cooperation with industry that anticipates and addresses the most important measurement and standards needs in a timely fashion." This focused the "best in the world" concept for programs by defining the nature of their objectives.

BFRL's 1998 Strategic Plan focused on its six major products and four additional objectives for measurements and standards with potential for best in the world status:

- Service life of building materials
- Metrology for sustainable development
- Earthquake, fire and wind engineering
- Advanced fire measurements and fire fighting technologies

The major budget increase for NIST laboratories for fiscal year 1998, was $3.8 million in wind engineering - but it was earmarked for Texas Tech University by Senator Kay Bailey Hutchinson who served on the Appropriations Committee. It displaced NIST's priorities for initiatives and made duplicative NIST's own fiscal year 1999 proposal for increased funding for wind engineering at NIST. BFRL was assigned to work with Texas Tech to define a strong program of research. This was done dutifully and well; sufficiently well that by fiscal year 2001, NIST was able to share in the appropriation and strengthen its wind research.

Substantial efforts were made to obtain budget initiatives for fiscal year 2000. Three led in BFRL were submitted by

NIST to the Department of Commerce: the initiative for PATH (partnership for advancing technology in housing); an initiative for PAIR (partnership for the advancement of infrastructure and its renewal) based on work with the federal agencies in the Subcommittee on Construction and Building and with industry; and a Disaster Mitigation initiative based on collaboration with NOAA and other bureaus of the Department of Commerce. All fared well enough to be included in a Livable Communities proposal by the President's Office of Science and Technology Policy in December 1998. However, none became part of the President's proposal for his 2000 budget.

One great highlight of fiscal year 1998 was that BFRL received funding to build the smoke abatement system for the fire laboratory from NIST's appropriation for renewal of facilities. Finally, in 2001, BFRL was again able to conduct medium and large scale fire tests in its own laboratory.

BFRL's Success Strategy was cited by NIST director Ray Kammer as probably "best in NIST" for reallocation of resources. In addition to the major products, the remainder of BFRL's directly appropriated funds were allocated systematically using the Analytical Hierarchy Process standardized for ASTM by BFRL's own Office of Applied Economics. The Success Strategy received support from NIST, the Assessment Panel for BFRL, and BFRL staff, but it succeeded at best at keeping a near-level effort for BFRL in the tight budget environment after the mid term elections of 1994. "Success" was a success in maintaining a healthy BFRL, but failed to achieve laboratory growth.

In its program review for the NIST Executive Board, BFRL cited a number of $100 million scale impacts of its program:

- Guidelines for the Seismic Rehabilitation of Welded Steel Frames, developed with the American Institute of Steel Construction, to make cost effective multi-billion dollars in rehabilitations.
- Expert System for Highway Concrete to guide materials selection and repair techniques for the multi-billion dollar highway pavement market.
- Alternate Refrigeration Systems to increase U.S. markets for environmentally friendly refrigerants and equipment and to reduce energy costs.
- Building Automation Protocol to increase market for U.S. products, and to save in installation, operation and maintenance costs.
- Moisture modeling to save over $100 million annually in energy costs of wet insulation and in repairs of degradation caused by wet insulation.
- Fire Modeling to save construction and rehabilitation costs by allowing performance based design of fire safety systems.
- Environmentally friendly fire suppressant systems to prevent airplane fires and reduce costs of retrofits to environmentally friendly systems.
- Life cycle cost assessment of high performance concrete for highway bridges shows state highway engineers how to achieve annual savings of $700 million.

The Industrial Fire Simulation System, developed by David Evans and colleagues, showed the capability to model the interactions of sprinklers, draft curtains and vents in a simulation of a warehouse fire. The simulation capability is very valuable for design of fire safety systems since a single full scale test, covering only one set of variables, costs about $50,000.

William Stone and colleagues demonstrated BFRL's National Construction Automation Testbed that combined real time construction site metrology and virtual reality simulations to allow construction automation hardware and software to evaluated for on site performance. Wireless real time metrology and simulation capabilities will support automation and remote control for safety and productivity in construction.

Robert Chapman and Roderick Rennison published the first two studies of baseline and progress measurements for the National Construction Goals. These studies described data sources, data classifications and hierarchies, and the metrics for the baselines and progress for the goals on project delivery time and on life cycle operation, maintenance and energy costs.

S. Shyam Sunder, chief, Structures Division

They defined an approach applicable to all of the goals.

S. Shyam Sunder became Chief of the Structures Division. Sunder joined BFRL in 1994 as Manager of the High Performance Construction Materials and Systems Program after 14 years on the Civil Engineering faculty of MIT, and served in the Office of the NIST Director as program analyst and senior program analyst from June 1996 to December 1997. H.S. Lew, who served as division chief from 1989 to 1997, continued as senior research structural engineer with major responsibilities in earthquake engineering and national and international standardization.

Richard Marshall received the first Walter P. Moore Award of the American Society of Civil Engineers for his career contributions to wind engineering standards - a most timely recognition as Marshall entered the final stages of a mortal illness. Dale Bentz received the L'Hermite Award of RILEM for his seminal contributions to the modeling of the microstructure and properties of concrete.

6.10 1999

Richard Wright retired as director of BFRL at the end of January 1999. Jack Snell succeeded him as BFRL director and James Hill succeeded Snell as deputy director. Wright retired pleased with the accomplishments of CBT/BFRL's researchers and managers, often under adverse circumstances, in his years as director, and regretful that BFRL had not achieved the scope, size and funding needed to meet the measurement and standards needs of the construction and fire safety communities. This history overall tells the story of the accomplishments and frustrations in some detail.

The year was tight financially without new directly appropriated funding and other federal agencies also limited in their funding for BFRL. BFRL had focused directly appropriated funding increasingly on new areas such as FIATECH and Cybernetic Building Systems. BFRL developed a marketing program for its managers and senior researchers to improve prospects for funding from other federal agencies and the private sector. NIST director Ray Kammer also made central allocation funding available to support earthquake, fire, and wind engineering temporarily because initiatives were not funded by Congress.

Jack Snell's work over two years with the Breakthrough Research Committee of the Construction Industry Institute (CII) led to the organization of the FIATECH (Fully-Integrated and Automated Project Process Systems and Technologies) Consortium. FIATECH brought major owners of constructed facilities, engineering construction firms, and suppliers of information technology hardware and software into a collaborative effort with BFRL to reduce project delivery time and cost. The focus was on seamless integration of project information through the whole life cycle and by bringing real-time wireless data from the construction site into project management information systems. Richard Jackson retired as director of NIST's Manufacturing Engineering Laboratory to lead the FIATECH Consortium. The BFRL major product Computer-Integrated Construction Environment evolved into Construction Integration and Automation Technologies (CONSIAT) to align itself with a major theme of FIATECH.

The Cybernetic Building Systems major product aimed at performance measurement and evaluation tools and open systems protocols for integrated, intelligent building service systems providing optimal control, fault detection and diagnostics for energy management, real-time purchase of electricity, fire and security, transportation, and aggregation of sets of buildings. BFRL works with industry, building professionals, ASHRAE and trade organizations, university researchers

and other government agencies to prepare a Virtual Cybernetic Building Testbed and conduct a full-scale demonstration of a Cybernetic Building System in a government office building complex.

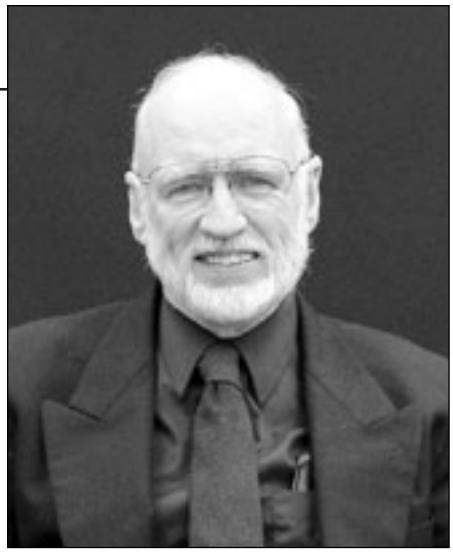
Jeffrey Gilman and Takashi Kashiwagi demonstrated that polymer-clay nanocomposites fulfill requirements for high-performance additive type flame retardant systems for polymers. Flammability is reduced while improving other properties of the polymer. A consortium of eight companies and three government agencies has been formed to study the nanocomposites' flame retardant mechanism.

Richard Gann stepped aside from Chief of the Fire Science Division, a position he had held since 1982, to focus on leading the interagency effort to remove dependence on ozone-depleting halon fire suppressants, guidance to U.S. manufacturers in exporting to countries with diverse fire test requirements, and developing a scientifically sound basis for determining when and how to include the sublethal effects of smoke in fire safety decisions.

William Grosshandler, who joined BFRL in 1991 as Leader of the Fire Sensing and Extinguishment Group after three years as Director of the Thermal Systems Program of the National Science Foundation, became chief of the Fire Science Division. At BFRL Grosshandler enthusiastically and efficiently led highly successful interdisciplinary teams in understanding the mechanisms of fire suppression and in expanding capabilities for calibration of heat flux measuring devices.

George Kelly became chief of the Building Environment Division. Kelly joined NBS in 1970 and led development of work in building automation and control systems as leader of the Mechanical Systems and Controls Group since 1980. His quiet manner hides great technical insight and imagination and unstinting efforts to meeting commitments on time, target and budget.

Noel Raufaste retired from BFRL as Manager, Cooperative Research Programs, at the end of December 1998 to become Managing Director, Technical and International Activities, for the American Society of Civil Engineers. Raufaste joined CBT's Office of Federal Building Technology in 1972 to develop, oversee and participate in research projects for federal agencies. He continued these efforts throughout his years with CBT and BFRL, and represented CBT/BFRL in the National Science and Technology Council's Subcommittee on Natural Disaster Reduction, the Federal Facilities Council of the National Research Council, for which he served on the Program Committee and as Vice Chair, and on the Consultative Council of the National Institute of Building Sciences, which he chaired for a term. He developed a major cooperative research program with the

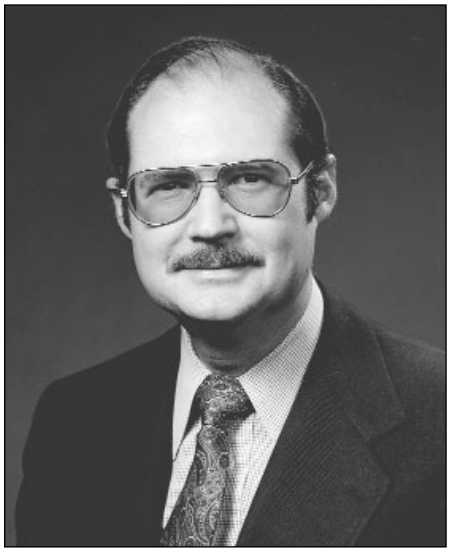


George Kelly, chief, Building Environment Division.

General Services Administration which was an important source of funds for CBT and CFR in the 80s.

Raufaste also led CBT's and BFRL's efforts to communicate effectively with the building and fire communities at large - supplementing the traditional communication of researchers with their peers and the direct users of their research in standardization and similar activities. He designed and developed project summaries, reports on publica-

Noel Raufaste, lead BFRL's cooperative research programs for a quarter century.



tions, newsletters and videos to inform and attract potential collaborators in and users of CBT/BFRL research. A number of these products received national awards for their quality.

He coordinated CBT's international activities during the early and mid 1970s and later coordinated collaborations with several European building and fire research laboratories He served as the U.S. side Secretary General for the U.S./Japan Panel on Wind and Seismic Effects from 1985-1999, organized and coordinated its highly productive technical committees, and arranged funding for its work by U.S. agencies. For a quarter century, Raufaste worked effectively with foreign science diplomats from about 20 foreign embassies in Washington, DC to help them learn about NBS/NIST research and to gain access to foreign research. In addition, he provided staff support for the program planning activities of CBT/BFRL. His enthusiasm and unstinting efforts earned the respect of colleagues in BFRL and collaborating organizations.

6.11 2000

BFRL initiated this last year of the 20th century with a self assessment and action plan following the criteria of the Malcolm Baldrige National Quality Award. The resulting mission and vision became:

Mission: *Meet the ongoing measurement and standards infrastructure needs of the Building and Fire Safety Communities.*

Vision: *The source of critical tools - metrics, models and knowledge - used to advance the communities we serve.*

The assessment showed that NIST, through BFRL, has growing opportunities and is driving major changes while facing shrinking resources. The outcomes envisioned were:

- Innovative Materials: enable the next generation materials for construction and building products.
- Enhanced Building Performance: provide means to assure that buildings work better throughout their useful lives.
- Fire Loss Reduction: enable engineered fire safety for people, products, facilities, and first responders.

The shrinking resources were a serious problem. BFRL management was required to announce a reduction in force affecting a number of its most renowned and productive researchers to show NIST management that without additional resources BFRL could not respond to new demands and opportunities without terminating established and productive work. NIST responded with reallocation of resources that allowed cancellation of the reduction in force.

Moreover, BFRL succeeded in gaining new funding in wind engineering and technologies for fire fighter safety through Congressional appropriation for fiscal year 2001 that put BFRL on a sound financial basis for the beginning of the new century.

At the end of the year, the Fire Safety Engineering Division and the Fire Science Division were merged into the Fire Research Division with William Grosshandler as chief. This provided a single focal point at NIST for fire research and recognized the attrition of fire research funding and staff since the Center for Fire Research was organized in 1974. However, the quality and impact of BFRL's fire research continue to grow as shown by the descriptions herein of the work.

Another evidence in 2000 of the success of BFRL fire research was the election of Howard Baum to the National Academy of Engineering in recognition of his research on fluid mechanics of fire, turbulent combustion and the development of efficient large eddy simulation methods for turbulent combustion. Baum joined NBS in 1975, received with Ronald Rehm one of the first competence project awards in 1978 for the beginning of the large eddy simulation method and was selected as NIST Fellow in 1983. His influence on fire research and practice extends far beyond his own work. Baum delights in collaboration with and development of young researchers to become independent leaders in fire science and engineering.

The work of Howard Baum and colleagues in collaboration with industry was made available to fire protection engineers, designers and investigators with release of the Fire Dynamics Simulator (www.fire.nist.gov). The NIST Fire Dynamics Simulator consists of two programs, FDS and

Smokeview. The NIST Fire Dynamics Simulator predicts smoke and/or air flow movement caused by fire, wind, ventilation systems etc. Smokeview visualizes the predictions generated by NIST FDS. FDS, solves a form of the Navier-Stokes equations appropriate for low-speed, thermally-driven flows of smoke and hot gases generated in a fire. Kevin McGrattin and Glenn Forney received the Department of Commerce Silver Medal in 2001 in recognition of this work.

David Didion was awarded the first Gustov Lorentzen Prize of the International Institute of Refrigeration for his pioneering work in refrigeration research and in the search for alternatives to CFC refrigerants. Didion joined NBS in 1971 and decided after a year in the NBS Director's Office in 1972-73 to focus on technical work rather than management. However, his great effectiveness in working with leaders of industry and other agencies, in developing young researchers including part time teaching of graduate courses and supervision of theses, in conceiving and conducting innovative research programs to produce changes in practice, and in candid assessments of managerial fads and initiatives extended his influence far beyond his own, very influential work. He conceived and initiated highly successful CBT/BFRL research in mechanical systems and controls as well as initiating and leading his prize winning research on alternative refrigerants and on refrigeration cycles to increase their efficiency.

The work of Jonathan Martin and colleagues enabled reliability-based predictions of the service lives of polymeric materials. Outdoor exposures are characterized by time series of temperature, moisture and ultra-violet exposure; laboratory and field studies define mechanisms of degradation and formulate cumulative damage models which then are used for rational, probabilistic predictions of service life.

The work of John Gross, in cooperation with the American Institute of Steel Construction (AISC) and several leading universities, to develop guidance for the rehabilitation of welded steel moment frames to improve their seismic resistance, was published as AISC Design Guide 12, Modification of Existing Welded Steel Moment Frame Connections for Seismic Resistance. In 2002, John Gross received the Department of Commerce Bronze medal for this work and the American Society of Civil Engineers (ASCE) Raymond C. Reese Research prize for a related paper.

The work of William Stone and colleagues in cooperation with Pankow Construction to develop hybrid connections for precast concrete frame systems was implemented in the building authorities' approval for construction of the tallest reinforced concrete building in California - a 39 story apartment in San Francisco. Stone, Geraldine Cheok, and H.S. Lew received the Department of Commerce Silver Medal for this work in 2001.

6.12 CONSTRUCTION AND BUILDING SUBCOMMITTEE, NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

This section is included as a management topic in building and fire research history because it was a major concern of BFRL management and concerned program development rather than technical work.

At its beginning, the Clinton Administration gave priority to economic growth [9], and particularly to technologies for economic growth [10]. President Clinton established the National Science and Technology Council (NSTC) by Executive Order on November 23, 1993, to coordinate science, space and technology policies across the federal government. The President chaired NSTC; members included the Vice President, the Assistant to the President for Science and Technology, Cabinet Secretaries and Agency Heads with significant science and technology responsibilities, and other White House officials. Mary Good, Undersecretary of Commerce for Technology, chaired the NSTC's Committee on Civilian Industrial Technology (CCIT) which was charged to collaborate with industry to enhance the international competitiveness of U.S. industry through federal technology policies and programs.

BFRL's mission already was well aligned with the thrusts of NSTC and

CCIT: to enhance the competitiveness of U.S. industry and public safety through performance prediction and measurement technologies and technical advances that improve the life cycle quality of constructed facilities. At its meeting of December 7, 1993, CCIT discussed establishing a Subcommittee on Construction and Building (C&B). Richard Wright worked with Mary Good and with Henry Kelly and Cynthia Arnold-McKenna of the President's Office of Science and Technology Policy (OSTP) to organize C&B. Kelly in 1988, while with the Office of Technology Assessment, had worked with Arthur Rosenfeld, Director of the Center for Building Science of the Lawrence Berkeley Laboratory (LBL), to outline proposed National Institutes for the Built Environment, modeled on the National Institutes of Health. At the suggestion of OSTP, Wright and Rosenfeld became co-chairmen of C&B. Rosenfeld, originally a nuclear physicist, applied his drive and imagination to energy conservation technology and policy following the energy crisis of 1973 and led the development of LBL's major energy conservation program.

Rosenfeld immediately arranged substantial funding from the Department of Energy for C&B to match that provided by BFRL. Andrew Fowell of NIST accepted the secretariat of C&B. Thomas Anderson, a Fluor Daniel executive on an AAAS fellowship to RAND Corporation's Critical Technologies Institute, provided liaison for C&B to OSTP. The Civil Engineering Research Foundation (CERF), led by Harvey Bernstein, expressed interest in convening private sector interests to participate in the C&B program. A planning group including representatives of the Department of Defense, Housing and Urban Development, and National Science Foundation met on March 2, 1994, and additional inputs were obtained from the Environmental Protection Agency, Federal Highway Administration, and Health and Human Services. A proposed Program Description for C&B was submitted to CCIT on March 7, and CCIT established the subcommittee on March 18, 1994.

C&B met on March 25, to agree on its vision, mission and goals [11].

Vision

- High quality constructed facilities support the competitiveness of U.S. industry and everyone's quality of life.
- U.S. industry leads in quality and economy in the global market for construction products and services.
- The construction industry and constructed facilities are energy efficient, environmentally benign, safe and healthful, and sustainable in use of resources.
- Natural and manmade hazards do not cause disasters.
- Intelligent renewal, a process that cost effectively uses limited economic, material and human resources, is applied to rebuilding America.

Mission

Enhance the competitiveness of U.S. industry, public safety and environmental quality through research and development, in cooperation with U.S. industry, labor and academia, for improvement of the life cycle performance of constructed facilities.

Goals, which came to be known as the National Construction Goals, were made quantitative to show policy makers in industry and government the importance of the program.

1. 50 percent reduction in project delivery time.
2. 50 percent reduction in operation and maintenance.
3. 30 percent increase in productivity and comfort.
4. 50 percent fewer occupant related illnesses and injuries.
5. 50 percent less waste and pollution.
6. 50 percent more durability and flexibility.
7. 50 percent reduction in construction related illnesses and injuries.

The baseline for the goals was current construction practices, and the target was to have technologies and practices capable of meeting the goals available to the industry by 2003.

On April 5, 1994, CERF convened a broadly based focus group of industry leaders to discuss the C&B program. The program and goals were endorsed enthusiastically [12].

On May 6, 1994, Leon Panetta, Director of the Office of Management and Budget, and John Gibbons, Director of the Office of Science and

Technology Policy, issued FY 1996 Research and Development Priorities to the heads of executive departments and agencies. Three of the seven cited priorities for research related to the program of C&B:

- Construction and Building. Activities that support the residential/commercial building construction industry and its suppliers in the development of advanced technologies aimed at increasing the productivity of construction, improving product quality (including energy efficiency and improved air quality), use of renewable resources, and increased worker health and safety. Focus areas will include the development and demonstration of systems for constructed facilities exploiting advanced construction materials; advanced design, modeling and engineering tools for concurrent engineering design and life-cycle monitoring and maintenance; automated construction methods; and improved building systems such as sensors and control, fire safety systems, advanced glazing, and lighting systems.
- Materials Technology. Emphasis will be placed on materials processing for specific industry sectors, in particular automotive, electronics, construction, environmental technologies, and aeronautics.
- Physical Infrastructure for Transportation. Activities will include improved materials, monitoring instruments, tools, construction methods, and design concepts for the construction and renewal of the physical infrastructure.

Wonderful! For the first time in the experience of any of the veteran federal officials serving on C&B, an administration had given top priority to research to improve construction and constructed facilities. C&B proceeded to define a program of research to meet its goals [13], and to develop partnerships with the private sector to fund and conduct the needed research, development and demonstration [14, 15, 16]. The agencies participating in C&B planning and program development were the departments of Agriculture, Commerce, Defense, Energy, Health and Human Services, Interior, Labor, Transportation, and Veterans Affairs, and the Environmental Protection Agency, General Services Administration, National Aeronautics and Space Administration, and National Science Foundation.

Because the different sectors of the industries of construction had distinct needs and priorities, the development of collaborations with industry were divided into four sectors with an appropriate private sector organization coordinating each sector's efforts:

1. Residential, coordinated by the National Association of Homebuilders Research Foundation.
2. Commercial and Institutional, coordinated by the National Institute of Building Sciences,
3. Industrial, coordinated by the Construction Industry Institute.
4. Public Works, coordinated by the American Public Works Association.

The Administration's loss of both houses of Congress in the 1994 elections made the Administration's budget priorities for FY 1996 irrelevant to Congress. C&B received sustained priority in the Administration [17] and focused its efforts on developing collaborations with industry that would be attractive of Congressional support [18]. C&B studied existing federal research supporting the industries of construction and showed that it amounted to $500 million per year [19]. Focusing and coordinating federal R&D for construction, in cooperation with industry, to address the National Construction Goals clearly was of important public interest. A Collaborations Workshop [20] was conducted to make industry organizations aware of the mechanisms existing for collaborative research with the federal agencies.

The Residential Sector, led by Liza Bowles, president of the National Association of Homebuilders Research Foundation, moved vigorously to define a program meeting its priority goals [21]. In December of 1996, Rosenfeld and Wright agreed with Mary Good, Undersecretary of Commerce for Technology, and Henry Kelly, of the Office of Science and Technology Policy (OSTP), to organize a major program with the residential industry. David Engel of Housing and Urban Development (HUD), John Talbott of the Department of Energy (DoE), Joel Zingeser of BFRL, and Mark Bernstein of OSTP led the effort to organize the Partnership for

Advancing Technology for Housing (PATH). Bernstein used effectively the leverage of "calling from the White House" to attract participation of industry leaders, and Engel, Talbott and Zingeser, built on their agencies' extensive experiences in collaborations with industry and Congress to develop the program. PATH was announced by President Clinton on May 1998 [22], and HUD received an increase of $10 million for PATH in its FY 1999 budget to reverse a 25 year decline in HUD's funding for housing technology. NIST proposed budget increases for PATH for both FY 1999 and FY 2000, but did not give either sufficient priority with the White House to make it part of the President's Budget Proposal to Congress. However, HUD allocated a substantial portion of its budget for PATH to BFRL for technical support.

The Construction Industry Institute (CII) informed C&B that it would not collaborate formally with C&B, but would welcome participation of federal agencies in its programs addressing its goals (which were consistent with those of C&B). BFRL became a member of CII, as representing the Department of Commerce, and a number of other C&B agencies already were CII members. CII sponsored a workshop [23] to explore research needs and opportunities with C&B, and made a commitment to "breakthrough research" in its strategic plan. CII's program in Fully Integrated and Automated Project Processes (FIAPP) and its FIATECH Consortium resulted from these collaborations.

From the beginnings of its interactions with industry [12], C&B was told that barriers to innovation in construction practices and products were severe disincentives to increased private sector investments in research. Among principal barriers were 1) the multiple approvals of innovative products required by federal agencies and the regulatory authorities of state and local governments, and 2) the multiple, uncoordinated reviews and approvals imposed upon construction projects by the regulatory authorities of federal, state and local governments. To address the first barrier, C&B agencies supported the formation of nationally recognized evaluation centers: for building products by the International Code Council and CERF, and for highway, environmental and civil engineering products by CERF. To address the second barrier, C&B funded the National Conference of States on Building Codes and Standards (NCSBCS) to develop a program for Streamlining the Building Regulatory Process [24]. The Streamlining program identified, and made available nationally, best practices used successfully in various localities [25]. Because of the potential for information technologies for efficient sharing of information by project proponents and regulatory authorities, the Streamlining Project has evolved into NCSBCS's National Alliance for Building Regulatory Reform.

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